

**Evaluation of the VLBI2010 Survey
of the IVS Network Stations**

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Version: 2011-01-27



January 2011

Introduction

On December 2, 2010, the VLBI2010 Project Executive Group (V2PEG) of the International VLBI Service for Geodesy and Astrometry (IVS) sent a letter and survey form to 31 IVS network station heads or project managers. The goals of the survey have been (a) to gather information about VLBI2010 plans at existing IVS network stations, (b) to trigger VLBI2010 discussions at the network station level, and (c) to get input on what the V2PEG can do to best support individual VLBI2010 projects. Copies of the letter and survey form are attached.

As of January 15, 2011, 30 of the 31 stations had replied, a 97% return rate. Completed survey forms are compiled and attached in StationSurvey2010Analysis.pdf.

Executive summary

VLBI2010 is characterized by continuous observations (24/7), 30-s slew-track cycles, and broadband frequency coverage (2–14 GHz). These characteristics are necessary to meet the VLBI2010 (and GGOS) performance goals of 1-mm position error and 0.1-mm/yr site velocity error which have been identified as long term goals of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). They demand a new class of radio telescope that is fast moving ($v_{Az}=12^\circ/s$, $v_{El}=6^\circ/s$, $a_{Az,El}=3^\circ/s^2$) and has a suitable geometry to accommodate wideband feeds. In 2012 the first VLBI2010 prototype, the Twin Telescope Wettzell, will become operational.

The survey showed that up to 20 new radio telescopes at 17 sites with full VLBI2010 compliance could become operational by 2017. This number is based exclusively on the present IVS network station survey and does not reflect the possibility of new institutions joining in.

In addition 13 other radio telescopes (some of them co-located with the above new telescopes) will be operated with partial VLBI2010 compliance, the most common shortfall being limitations of radio telescope slew speed.

By 2014/2015 a sufficient number of VLBI2010 compatible radio telescopes will be available for initial VLBI2010 operations. A depiction of the evolution of the VLBI2010 network from 2011 to 2017 is attached in VLBI2010NetworkEvolution.pdf.

The V2PEG will provide support for the planning, preparation, and justification of VLBI2010 proposals and for the technical specification of new VLBI2010 stations. The group will accommodate as best as it can requests for in-person meetings with representatives of funding agencies.

Analysis

General remark: There is a wide variation in the stages of development of the projects reported in the VLBI2010 network station survey. In a few cases, stations have already begun construction of new radio telescopes. In the majority of cases, however, stations are somewhere in the planning/proposal phase. Although the V2PEG is aware of the uncertainty of receiving funds for planned projects, this analysis counts all projects with equal (and full) certainty. Therefore it must be considered a „success-oriented“ analysis.

Question 1: *Specify plan to upgrade your site to full VLBI2010 capability:*

(Options: a. pair of VLBI2010 radio telescopes at one site, b. one VLBI2010 radio telescope at one site, c. upgrade of legacy radio telescope, d. other (specify)).

*[Note: Information about legacy radio telescopes comes from responses to **Question 3.**]*

The upgrade plans at current IVS network stations contain a variety of possibilities:

- 3 stations plan to construct a pair of identical new radio telescopes each compliant with the VLBI2010 kinematic parameters ($Az=12^\circ/s$, $El=6^\circ/s$):
 - Wettzell,
 - Ny Alesund, and
 - Onsala.

Their plans for the legacy telescopes differ considerably. Onsala plans to upgrade its legacy radio telescope to VLBI2010 electronics. Wettzell plans to keep the legacy radio telescope as S/X. Ny Alesund plans to dismantle the legacy radio telescope.

- 14 stations plan to construct a single new VLBI2010 radio telescope compliant with the VLBI2010 kinematic parameters ($Az=12^\circ\text{deg/s}$, $El=6^\circ\text{deg/s}$):
 - Kokee Park,
 - Badary,
 - Hartebeesthoek,
 - Matera,
 - Metsahovi,
 - Nanshan,
 - Sheshan,
 - Hainan,
 - Tsukuba,
 - Yebes,
 - Santa Maria,
 - Gran Canaria,
 - Flores, and
 - Zelenchukskaya.

Kokee Park and (probably) Matera plan to upgrade their legacy radio telescopes to VLBI2010 electronics. Badary, Hartebeesthoek, Metsahovi, Nanshan, Sheshan, Tsukuba, Yebes, and Zelenchukskaya plan to leave the legacy radio telescope as S/X. The stations at Hainan, Santa Maria, Gran Canaria, and Flores will be new stations and thus don't have legacy radio telescopes.

- 6 stations have a new VLBI2010 radio telescope with kinematic parameters less than the

VLBI2010 recommendation:

- Hobart (Az=5°/s, El=1.5°/s),
- Katherine (Az=5°/s, El=1.5°/s),
- Yarragadee (Az=5°/s, El=1.5°/s),
- Warkworth (Az=5°/s, El=1°/s),
- GGAO (Az=5°/s, El=1.5°/s),
- and Sejong22 (Az=5°/s, El=5°/s).

Hobart and GGAO plan to retain their legacy radio telescopes as S/X. Warkworth plans to bring a second radio telescope to S/X capability. Katherine, Yarragadee, and Sejong22 are new stations and don't have legacy radio telescopes:

- 11 stations don't have concrete plans for building new radio telescopes. 7 out of the 11 stations plan to upgrade their legacy radio telescopes to VLBI2010 electronics:
 - Kashima,
 - Koganei,
 - Medicina,
 - Noto,
 - Simeiz,
 - TIGO, and
 - Westford.

The remaining 4 stations at Fortaleza, O'Higgins, Svetloe, and Syowa plan to keep the legacy radio telescopes as S/X. Syowa is scheduled to be decommissioned in 2016.

- The VLBA network will upgrade to 4–8 GHz receivers, which may be used by future IVS VLBI2010 observing programs.
- The VERA network will observe the VLBI2010 developments and consider upgrade possibilities later.

In summary:

- 3 stations plan to construct a pair of new VLBI2010 radio telescopes.
- 14 stations plan to construct single new VLBI2010 radio telescopes.
- 6 stations have constructed single new VLBI2010 radio telescopes with slew speeds lower than recommended.
- 11 stations have no plans to construct a new VLBI2010 radio telescope.
- 8 legacy radio telescopes will be upgraded to VLBI2010 electronics.
- 16 legacy radio telescopes will continue to operate in S/X mode.
- 16 stations will operate more than one IVS radio telescope (in various combinations of modes).
- VLBA and VERA have no plans to upgrade to VLBI2010.
- There is a good density of VLBI2010 stations in Eurasia.

Conclusion: To achieve a more uniform global coverage of VLBI2010 stations, it is essential that more VLBI2010 radio telescopes be established on the American continents, in the Pacific region, and in Africa.

Question 2: Do you plan to acquire a new radio telescope that doesn't fully meet the VLBI2010 recommendations? If so, please specify some technical parameters (kinematics, feeds, backend)?

- 17 stations plan for full VLBI2010 compatibility.
- 13 stations plan for VLBI2010 compatibility in electronics but will not meet the VLBI2010 slew rate recommendation.
- 8 stations or networks (VLBA, VERA) do not plan to upgrade their systems.

Question 3: Whether or not you acquire a new radio telescope, do you plan to continue operating your existing legacy radio telescope into the future?

(Options: a. upgrade of electronics to VLBI2010 compatibility, b. leave it as is, c. other (specify))

- 10 legacy network stations plan to upgrade to VLBI2010 electronics: Onsala, Kashima, Koganei, Kokee Park, Matera (maybe), Medicina, Noto, Simeiz, TIGO, and Westford.
- 16 legacy network stations and 2 networks will continue in S/X mode: Badary, Fortaleza, GGAO, Hartebeesthoek, Hobart26, Metsahovi, Nanshan, O'Higgins, Sheshan, Svetloe, Syowa, Tsukuba32, Vera, VLBA, Warkworth, Wettzell, Yebes40, and Zelenchukskaya.
- 2 legacy network stations will be decommissioned: Syowa in 2016, Ny Alesund when replaced by a twin telescope.

Question 4: What is the best estimate of the year in which your new VLBI2010 capability will become operational?

2010 Hobart*

2011 Katherine*, Yarragadee*, GGAO*, Westford*

2012 Wettzell, Kokee Park*

2013 Yebes, Onsala

2014 Badary, Zelenchukskaya, Matera, Santa Maria, Kokee Park, Fortaleza* (if funded)

2015 Metsahovi, Gran Canaria

2016 Flores, Sheshan, Nanshan, Tsukuba

2017 Ny Alesund

? Hartebeesthoek

*less than full VLBI2010 kinematic parameters.

Conclusion: The anticipated VLBI2010 observation mode with 30-s slew-track cycles may become a reality in 2014. Continuous 24h/7d observations may start in 2015 when the VLBI2010 network becomes large enough and the concept of daylight-zone remote network control may be applied. Global coverage with fully compliant VLBI2010 radio telescopes depends on efforts made mainly in the American, Pacific, and African regions.

Question 5: *At what stage are you in the planning process?*

- a. *Already funded*
- b. *Proposal submitted*
- c. *Proposal in preparation*
- d. *Waiting for better timing in local funding cycle*
- e. *Waiting for an indication from the IVS that this is the right time to start*

- 8 network stations have projects already funded.
- 8 network stations have proposals submitted.
- 8 network stations have proposals in preparation.
- 6 network stations are waiting for a better timing in the local funding cycle.
- 2 network stations are waiting for an indication from the IVS that it is the right time to start.

Conclusion: The large number of network stations demonstrates the awareness at IVS network stations that VLBI2010 is considered important and worth undertaking efforts to realize it.

Question 6: *What support do you need from the IVS?*

- a. *Letter of support*
- b. *V2PEG member(s) to meet with local authorities or participate in a local workshop*
- c. *VLBI2010 questions answered*
- d. *Technical support writing specifications*
- e. *other (specify)*

- 18 network stations require a letter of support from the IVS.
- 7 network stations require V2PEG members to meet with local authorities or participate in a local workshop.
- 7 network stations need VLBI2010 questions answered.
- 18 network stations need technical support writing specifications.

The analysis of the quantitative distribution shows (a) a big demand for support on the bureaucratic level to demonstrate, for instance, by letters of support that the IVS is in the process of modernizing the global VLBI network infrastructure and (b) a big demand for technical assistance in getting the technical specifications right on what VLBI2010 is.

Conclusion: V2PEG should continue to draft tailored letters of support. V2PEG should address the need for technical information about VLBI2010 for the station staff. V2PEG might generate a prototype technical specification and the IVS might consider a dedicated workshop to promote it.

Question 7: Comments

The possibility to add comments was used only by a few network stations, specifically those that have already undertaken serious VLBI2010 project activities.

Wetzell asked for a clear VLBI2010 position on different feed solutions and for technical hardware support for feed and receiving equipment.

Ny Alesund pointed out the importance of remote control of radio telescopes in the VLBI network and asked whether this option will be technically developed—as it may impact on the number of staff necessary to run the remote station. If Ny Alesund gets a twin telescope, they would like to use both radio telescopes simultaneously. A proposal was made to share information and arguments that were successful in convincing funding authorities.

Tsukuba is concerned about the hydrological situation and the local survey with respect to VLBI.

VERA pointed out that they use the most precise global reference frame for their astrometric use. For that reason VERA participates in the IVS (T2 sessions). If the target accuracy can be reached by VLBI2010, VERA will consider VLBI2010.

Warkworth wants to develop VLBI2010 with respect to SKA and e-VLBI. Both items have high priorities in New Zealand and should be addressed in support letters.

Appendices

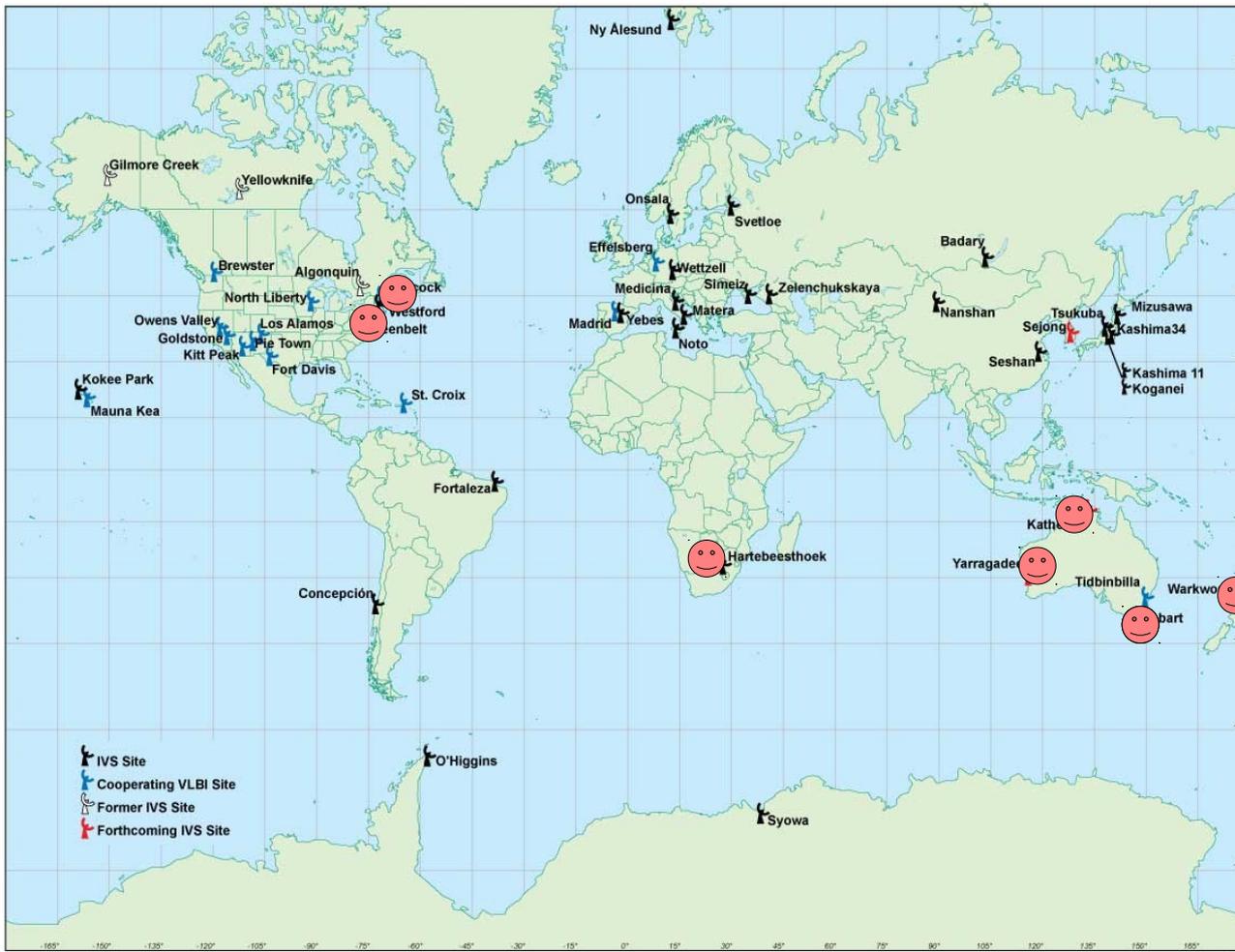
StationSurvey2010Analysis.pdf

VLBI2010NetworkEvolution.pdf

v2peg_station-survey20101201.pdf

Network Station	1. Upgrade Plan				2. VLBI 2010 compatibility			3. Legacy upgrade			4. VLBI2010 operational	5. Planning process						6. Support needed from the IVS					Comments
	a. >1 new radio telescopes	b. 1 new radio telescope	c. upgrade legacy	d. Other	a. Full	b. < full	c. No	a. Electronics	b. No upgrade	c. Other	a. Estimated year	a. Already funded	b. Proposal submitted	c. Proposal in preparation	d. Waiting for better timing	e. Waiting for indication of IVS	f. Other	a. Letter of support	b. V2PEG members to meet with local authorities	c. VLBI 2010 questions answered	d. Technical support writing specifications	e. Other	
Badary		1			1				1		2014		1					1			1		
Fortaleza				none			1	1		if money is available	2014 with legacy system						not considered	1		1	1		cost breakdown, partner and party identification required before application for funds
GGAO		1				1				S/X or Lindgren	2011	1											
Hartebeesthoek		1			1	1			1		?						exploring options and canvassing the funding agency					will approach IVS when finalized a concrete path	interim solution based on 15m SKA, definitive solution based on Patriot 2.0 when funded
Hobart26				no upgrade			1		1		N/A						N/A					N/A	
AuScope Hobart		1				1				s. Hobart26	2010	1		1				1		1	1		support for broadband required
AuScope Katherine		1				1					2011	1		1				1		1	1		support for broadband required
AuScope Yarragadee		1				1					2011			1				1		1	1		support for broadband required
Kashima34				no upgrade			1	1			2013			1				1	1	1	1		front and back end development
Koganei11				no upgrade			1	1			2013			1				1	1	1	1		front and back end development
Kokee Park		1	1		1	1		1			2014	1	1					1				1	twin infrastructure possible
Matera		1			1			1			2014				1			1				1	
Medicina			1			1		1	1	effort for upgrade	N/A				1			1				1	survey triggered discussion at IRA and INAF
Metsahovi		1			1			1			2015		1									1	
Nanshan		1			1			1	1		2016				1			1				1	
Noto			1			1		1	1	effort for upgrade	N/A				1			1				1	survey triggered discussion at IRA and INAF
Ny-Alesund	1				1					destruct old radio telescope	2017		1										remote control will be essential Both radio telescopes should be used in
O'Higgins				no upgrade			1	1	1		N/A												
Onsala	1		1		1			1	1		2013			1				1	1		1		V2PEG to meet with Swedish research council
Sejong22			1	KVG 2012 S/X		1		1			2015				1								VLBI operation and system support for novice station 2012
Sheshan		1			1				1		2016			1				1					
SHAO-Hainan		1			1				1		2016			1				1					new station Hainan Island
Simeiz			1			1		1					1					1				1	
Svetloe									1										1			1	
Syowa				no upgrade			1			Destruction 2016	>2016			1				1					
TIGO			1			1		1		Destruction 2016 recording upgrade	t.b.d.			1									future of TIGO currently not clear
Tsukuba32		1			1			1			2016		1					1	1	1	1		local survey concept is important due to hydrological annual cycle at site
VERA				keep system			1	1			depends on T-series of IVS				1								VLBI2010 has to proof its capabilities first before it is considered
VLBA				S-band, 4-8 GHz upgrade			1			recording upgrade	N/A												none at this time
Warkworth	1			12m + 30m		1							1					1					letter to upgrade 30m for S/X to AUT and minister of
Westford			1			1		1			2011	1											none at this time
Wetzell	1				1			1		if possible	2012						almost finished					finding new tasks for existing system	clear statements according to different feed solutions and technical hardware support for feed and receiving equipment design would be nice
Yebe40				no upgrade					1	S/X remains													
RAEGE Yebe		1			1						2013	1											
RAEGE Santa Maria		1			1						2014	1											
RAEGE Gran Canaria		1			1						2015	1											
RAEGE Flores		1			1						2016												
Zelenchukskaya		1			1				1		2014		1									1	
Total	4	18	8		17	13	8	14	14			8	8	8	6	2		18	7	7	18		

VLBI2010 Network in 2011



VLBI2010 full speed

☺ radio telescope

☺☺ twin radio telescope

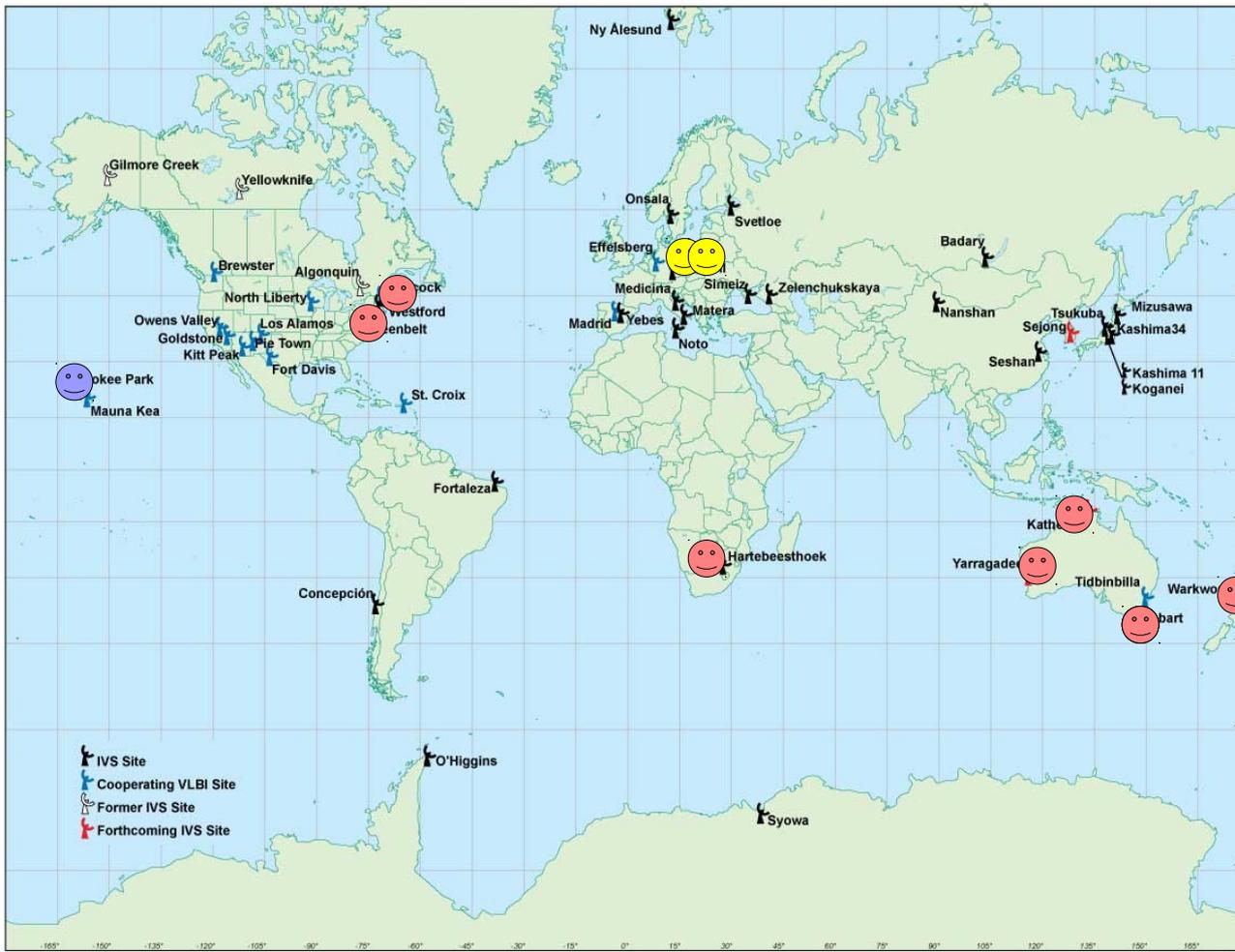
VLBI2010 low speed

☹ radio telescope

upgrade legacy

☹ radio telescope

VLBI2010 Network in 2012



VLBI2010 full speed

☺ radio telescope

☺☺ twin radio telescope

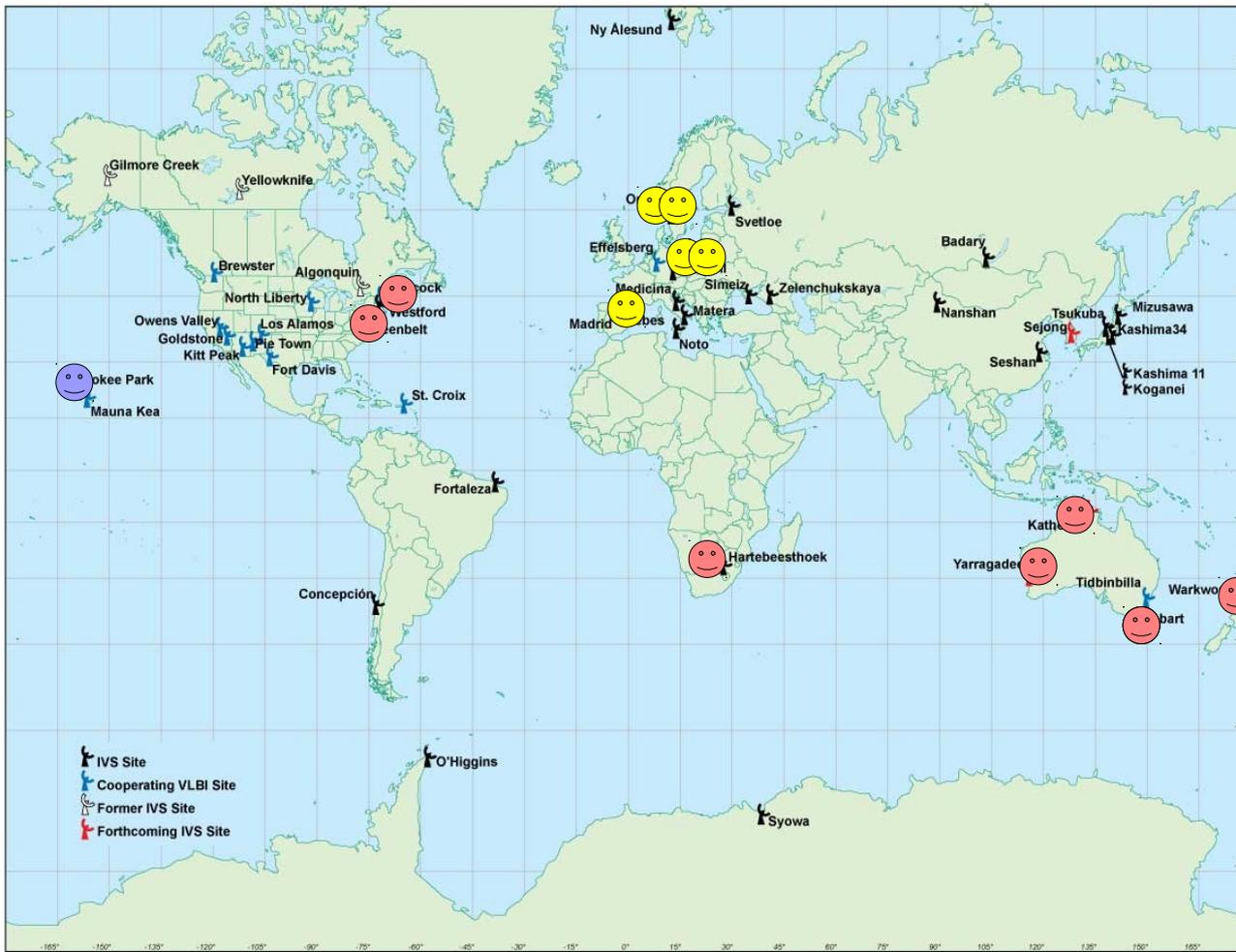
VLBI2010 low speed

☹ radio telescope

upgrade legacy

☹ radio telescope

VLBI2010 Network in 2013



VLBI2010 full speed

☺ radio telescope

☺☺ twin radio telescope

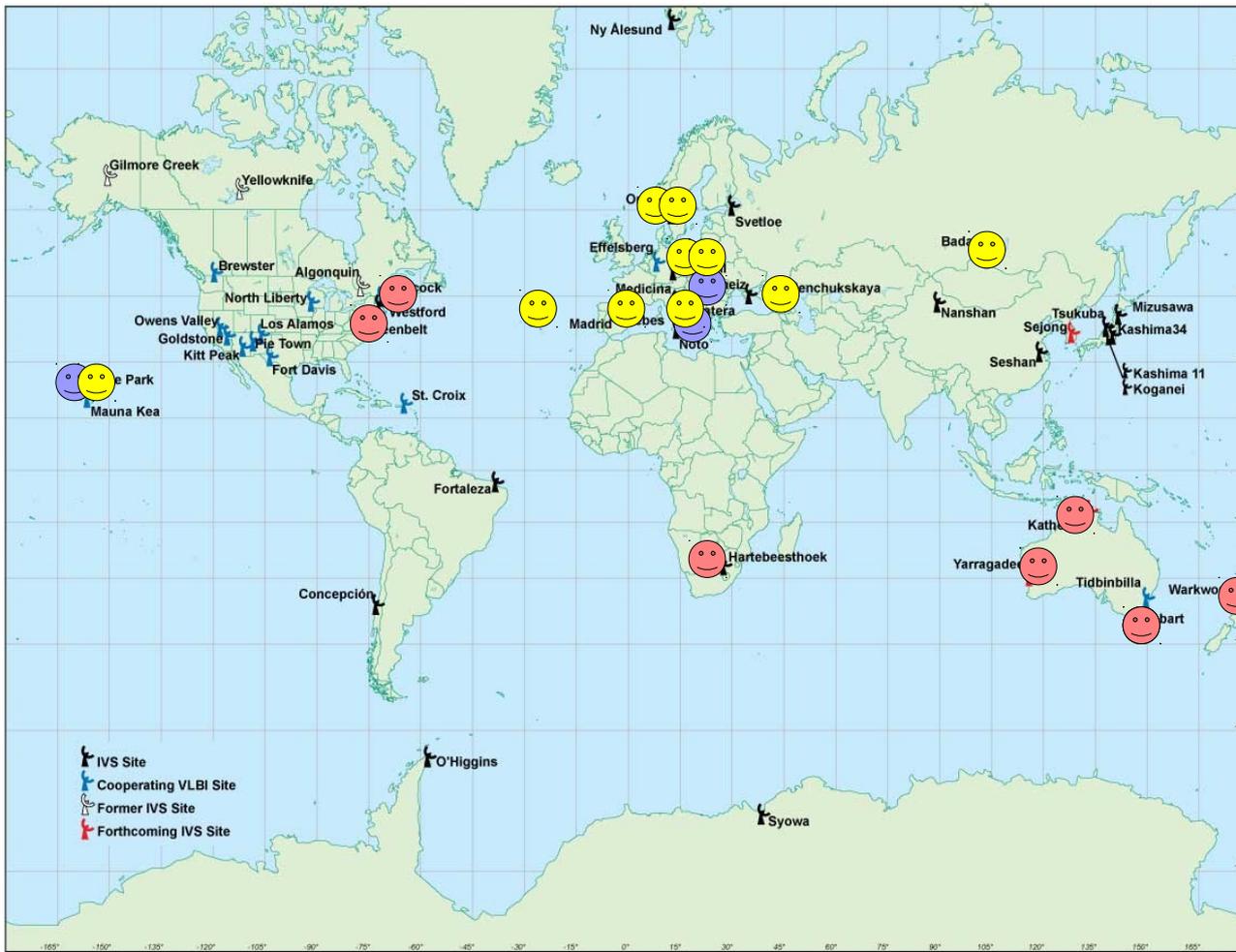
VLBI2010 low speed

☹ radio telescope

upgrade legacy

☹ radio telescope

VLBI2010 Network in 2014



VLBI2010 full speed

☺ radio telescope

☺☺ twin radio telescope

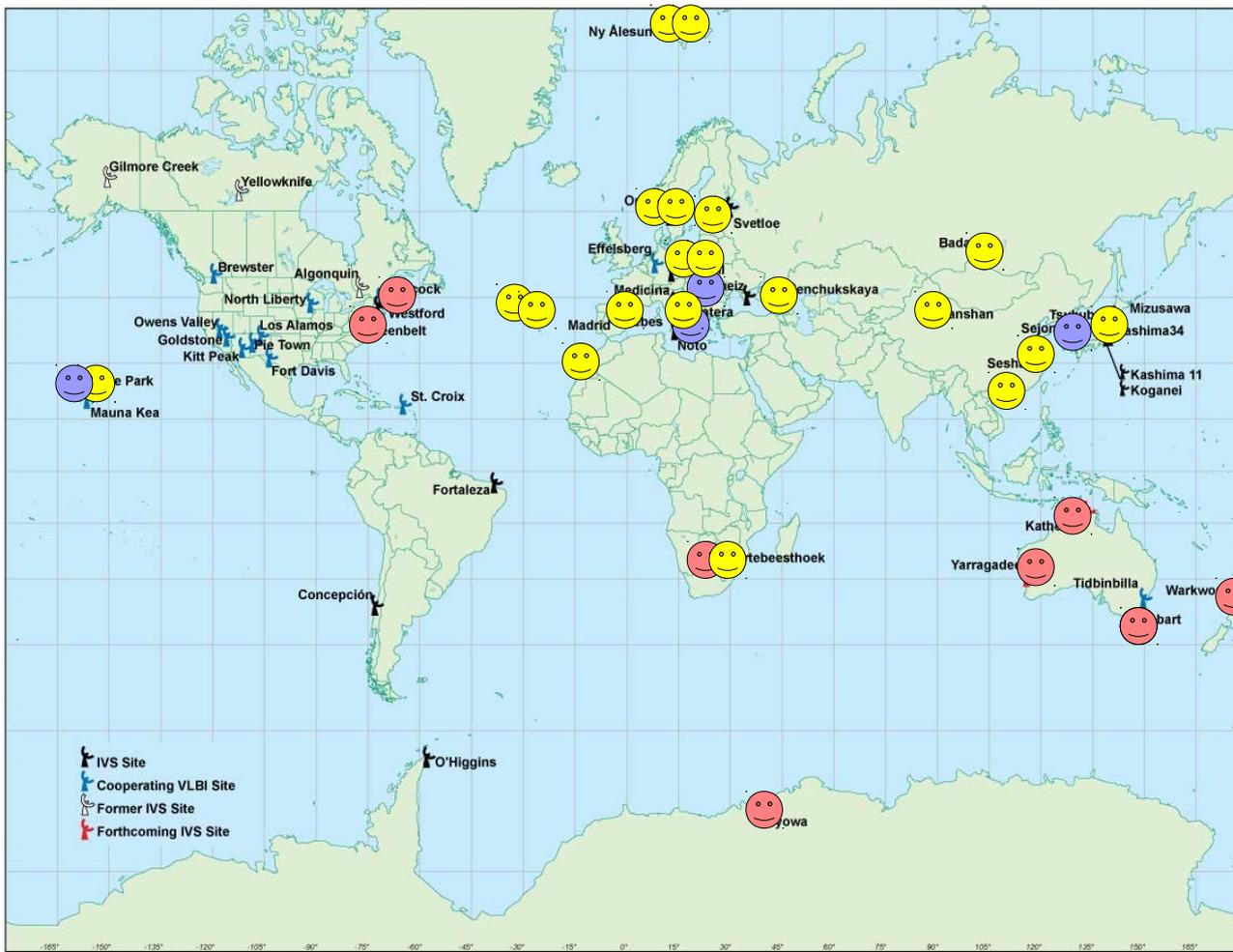
VLBI2010 low speed

☹ radio telescope

upgrade legacy

☹ radio telescope

VLBI2010 Network in 2017



VLBI2010 full speed

☺ radio telescope

☺☺ twin radio telescope

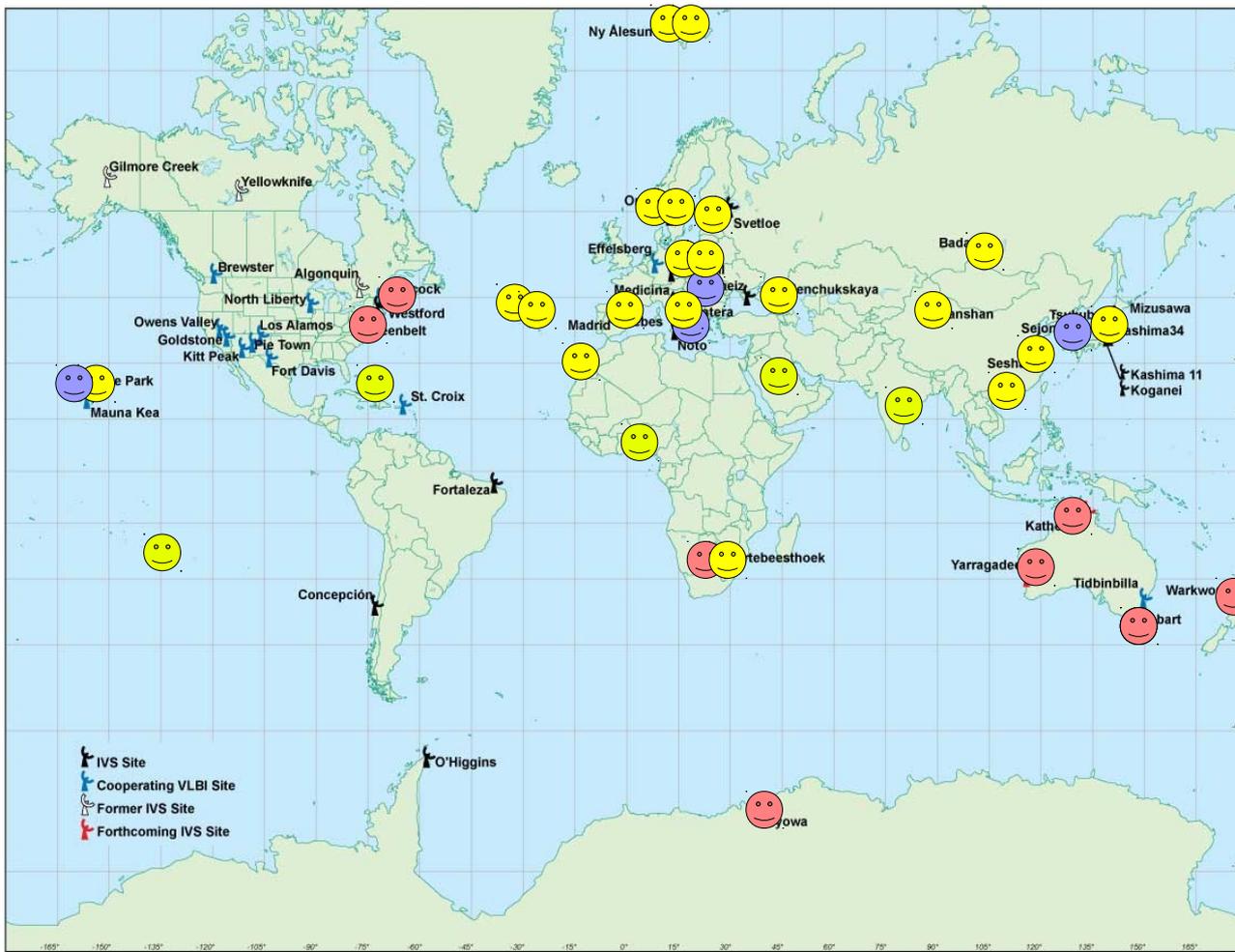
VLBI2010 low speed

☹ radio telescope

upgrade legacy

☹ radio telescope

VLBI2010 Network in 2017 including potential new sites



VLBI2010 full speed

☺ radio telescope

☺☺ twin radio telescope

VLBI2010 low speed

☹ radio telescope

upgrade legacy

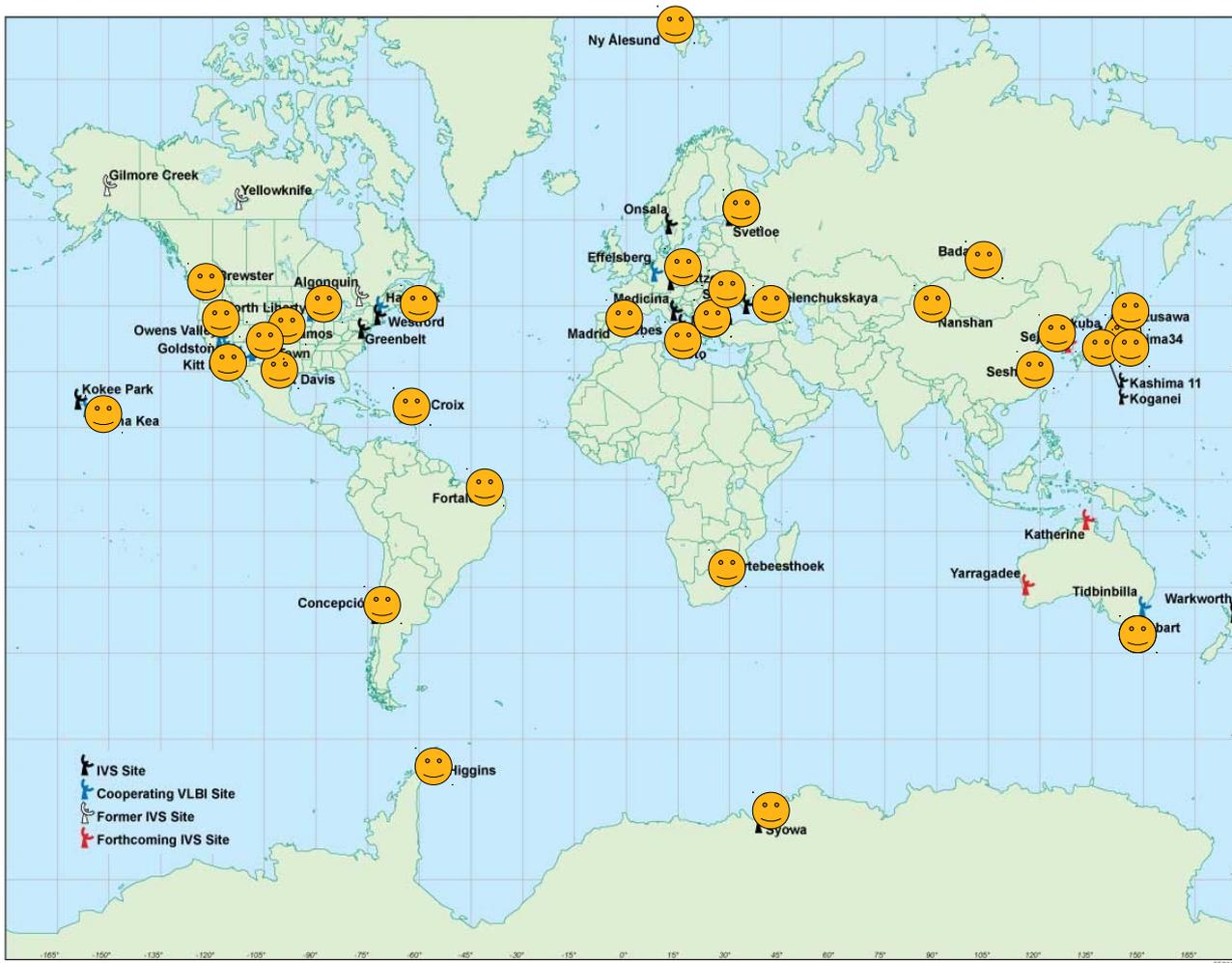
☹ radio telescope

potential new site

☺ radio telescope

VLBI2010 Network in 2015

S/X Network Stations



VLBI S/X-station

☺ radio telescope

Remarks

- missing years in survey estimated
- information about potential new IVS-sites only included in slide 8 (Tahiti, Arecibo, Arabia, etc.)
- missing information about NASA plans to support IVS with additional stations
- information of the introduction of the wideband feed/observation at existing sites is missing



**International VLBI Service
for Geodesy and Astrometry**

IVS Directing Board Members:

Harald Schuh, Austria
Chairman, IAG Representative
Dirk Behrend, USA
Coordinating Center Director
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December 1, 2010

To the IVS Network Station managers

Dear colleagues:

In recent years the International VLBI Service for Geodesy and Astrometry (IVS) has developed the concept and specifications of a next generation VLBI system called VLBI2010¹ based on the results of the Final Report² of IVS-Working Group 3. The goals of the new VLBI system are to achieve (on scales up to the size of the Earth):

- 1 mm position accuracy,
- 0.1 mm/yr velocity accuracy,
- continuous observations, and
- availability of results in near real-time.

These goals fully meet the requirements of the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). GGOS itself is based on several international Services such as the IVS and is part of the higher level Global Earth Observing System of Systems (GEOSS) initiated by the intergovernmental Group on Earth Observations (GEO), currently composed of 81 countries³.

The VLBI2010 system involves a nearly complete replacement of the currently used S/X system. It is based on a new class of fast ~ 12 -m radio telescopes ($v_{Az}=12^\circ/s$, $v_{El}=6^\circ/s$) that can support continuous 30s slew/track cycles for a 20-year lifetime, a new “broadband” receiving system with flexible frequency allocation anywhere in the continuous 2-14 GHz frequency range, expanded eVLBI, and enhanced automation and remote control.

1Find the complete document under

<ftp://ivscc.gsfc.nasa.gov/pub/misc/V2C/TM-2009-214180.pdf>

2http://ivscc.gsfc.nasa.gov/about/wg/wg3/IVS_WG3_report_050916.pdf

3http://www.earthobservations.org/ag_members.shtml

The IVS VLBI2010 Project Executive Group (V2PEG) is the group providing strategic leadership to VLBI2010. Now that VLBI2010 prototype development is well advanced, the V2PEG is focusing attention on the transition from the project's development phase to its implementation. The main purpose of this letter is to gather information about the VLBI2010 intentions of your site. This is required both to plan the manufacturing quantities of the new systems and to assess weaknesses in expected VLBI2010 network distribution.

The V2PEG is aware of the diversity of existing network stations and of the upgrade possibilities of station owners. Thus we have attached a questionnaire listing options of how you might contribute to the goals of VLBI2010 depending on the level of funding commitment. If you have questions regarding the questionnaire, please send them to: ivs-v2peg@gsfc.nasa.gov .

It would be good to receive questionnaire responses before 17 December 2010 so that this information can be included in the discussion within the IVS about strategic planning of the VLBI2010 project. Please note that any information you provide in response to this request will be used for planning purposes only and will in no way be taken as a commitment to the IVS. If you need more time for internal discussions, please let us know.

Thank you very much for your cooperation.

Best regards,

Hayo Hase*
Chair of the IVS VLBI2010 Project Executive Group (V2PEG)
Network Representative on the IVS Directing Board

*On behalf of the V2PEG
[Hayo Hase (Chair), Dirk Behrend, Chopo Ma, Bill Petrachenko, Harald Schuh, and Alan Whitney]

VLBI2010 Network Station Survey—Response Form

(recommended deadline: 17 December 2010; please save this file as “2010yourstationname.doc” and return it to ivs-v2peg@ivscc.gsfc.nasa.gov)

Network station name:

Responsible institution:

Responsible person:

Person, function of person, filling out this form:

Date:

1. Specify plan to upgrade your site to full VLBI2010 capability:
(Options: a. pair of VLBI2010 radio telescopes at one site, b. one VLBI2010 radio telescope at one site, c. upgrade of legacy radio telescope, d. other (specify))
2. Do you plan to acquire a new radio telescope that doesn't fully meet the VLBI2010 recommendations? If so, please specify some technical parameters (kinematics, feeds, backend)?
3. Whether or not you acquire a new radio telescope, do you plan to continue operating your existing legacy radio telescope into the future?
(Options: a. upgrade of electronics to VLBI2010 compatibility, b. leave it as is, c. other (specify))
4. What is the best estimate of the year in which your new VLBI2010 capability will become operational?
5. At what stage are you in the planning process?
 - a. Already funded
 - b. Proposal submitted
 - c. Proposal in preparation
 - d. Waiting for better timing in local funding cycle
 - e. Waiting for an indication from the IVS that this is the right time to start
6. What support do you need from the IVS?
 - a. Letter of support
 - b. V2PEG member(s) to meet with local authorities or participate in a local workshop
 - c. VLBI2010 questions answered
 - d. Technical support writing specifications
 - e. other (specify)

Comments: